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Driving Automotive Innovation and Federal Policies

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INTRODUCTION

The Law of Accelerating Returns describes how technology is created and adopted. It states that technology is not created incrementally in a linear fashion; instead, it is relatively stable and changes little until there is an inflection point, after which it grows geometrically. The most prominent examples of the Law of Accelerating Returns are computing (e.g., Moore's Law), communications (e.g., Gilder's Law) and DNA sequencing (e.g., $1000 genome). The Law of Accelerating Returns can also be used to describe the development of Connected and Autonomous Vehicles (CAV).

The concept of driverless vehicles has been around for over 50 years but little progress was made until the Defense Advanced Projects Agency (DARPA) received government approval for a cash-prize competition called the DARPA Grand Challenge. It's hard to argue that the DARPA Grand Challenge, and its subsequent Urban Challenge, were not inflection points for Connected and Autonomous Vehicles. Since these events, the pace of technology developments in this area has increased substantially leading to a significant disruption in many mobility-related markets. It is very likely that cars of the future will not be piston-powered vehicles driven by people; rather, they're more likely to be interconnected computers on wheels scheduled and controlled by autonomous algorithms and developed by IT companies. With a potential market of over $87B within 15 years, manufacturers are racing to grab their share of the market.

BENEFITS

Autonomous vehicle technology has the promise of solving many of today's transportation related problems. One of the most important benefits of CAV is its promise to significantly lower driving related deaths. Last year alone, there were over 40,000 fatalities in the US at a cost of over $410B – and more than 90% of those fatalities were due to human error. With the potential for human error removed, self-driving cars will reduce instances of accidents caused by driver error, drunk driving or distracted drivers.

Autonomous Vehicles can also improve access for the elderly, children and poor and can make public transportation more effective by solving the "last mile" problem. Solving this last mile problem reduces or eliminates the difficulty of getting to and from light rail and other public transit modalities, leading to increased utilization of public transit systems and better mobility for large segments of the US population.

Commuters may also save up to an hour every day. This savings of time will have many spin-off benefits from improved well-being to boosting the economy. According to the 2015 Urban

Mobility Scorecard, each year, Americans living in urban areas spend almost 7 billion hours in traffic, waste 3.1 billion gallons of fuel and lose around $160 billion due to traffic congestion. With CAV vehicles able to access up-to-the-minute data to help monitor traffic, as well as digital maps and other tools, they can determine the fastest, most efficient routes possible. Drive times between locations will be reduced as a result. All of this will result in less traffic, less congestion and less time and fuel waste. With the ability to optimize fuel consumption, new-age vehicles are also expected to reduce vehicle emissions by 60%.

Highway congestion can also be reduced with the implementation of platooning since high-tech sensors can react dramatically faster than humans, allowing the distance between vehicles to be drastically reduced. Therefore, vehicles will operate at higher speeds and require much less space between vehicles, leading to greater traffic throughputs. This will result in less traffic, improved efficiency in our highway systems and will reduce the need for future capital investments in our transportation infrastructure. Parking lots will also be affected since it is estimated that driverless cars can be parked with 15% less space.

DISRUPTION IN MARKETS

Predictions are that many markets will be affected as driverless cars become more numerous in societies around the globe.

The disruption has already started; autonomous cars will run the roads sooner than we expect. Joel Barbier points to numerous industries that are expected to change as a result. He states that "Business leaders in *all industries* can no longer take a "wait and see" approach. Companies must start being hyperaware by monitoring changes in their environment (which extends beyond what their competitors are doing); they must start making informed decisions and execute those decisions quickly to respond to the threat of autonomous vehicles. Further, company and government leaders must immediately address the impact on jobs and get serious about retraining efforts."

Some of the companies he identifies are obvious, such as auto manufacturing and auto repair. Others are less obvious. For instance, parking, law enforcement, insurance markets, real estate, hotels, media consumption, auto parts, lawyers and health care are just a few that will be impacted. And those are just some of the ones experts can think of. As with most disruptions, the biggest opportunities are ones that haven't yet been discovered.

CHALLENGES

There are significant challenges ahead that need to be solved. Four major categories of challenges include (1) technological, (2) regulatory, (3) skills shift and (4) liability.

Automated Driver Assist Systems in many new vehicles have progressed, but fall short of enabling the sensor systems to guide a vehicle without human input. In addition, sensor development, improvements in data integration, data fusion and artificial intelligence are not yet robust enough to provide the safety of fully autonomous vehicles.

Decisions are still being debated regarding the regulatory environment around autonomous vehicles. Having the federal government responsible for vehicle safety, as is currently the case with existing vehicles, seems most workable. If each state is allowed to set its own safety standards, the resulting milieu will drastically complicate the testing and certification of driverless vehicles. Either way, regulatory policies for product testing and certification will need to be data-driven and science-based to avoid overburdening the industry with regulations that stifle innovation. Chip manufacturers, software industry and defense are examples where this has been done well.

The move to autonomous vehicles will also cause a shift in the predominant skills necessary and the types of workers needed in the transportation industry and in their regulators. Currently, both fields are dominated by civil and mechanical engineers but will need to rapidly increase the percentage of computer science and electrical engineering professionals in the field.

The insurance industry is already beginning to struggle with the impact driverless vehicles will have on their industry – as are lawyers and Original Equipment Manufacturers (OEMs) as they wrestle with liability issues. Additionally, the number of traffic citations is expected to go down thereby reducing the amount of revenue available to those entities which currently benefit from driver-based vehicles.

CAV TECHNOLOGY OVERVIEW

The fundamental technology core in autonomy rest on a "sensor and signal processing chain" which roughly includes sensing, signal processing, networking, data fusion and artificial intelligence.

In this chain, sensors are responsible for perceiving an accurate description of the environment. Optical, microwave (radar) and lidar sensing each have advantages and disadvantages, and a robust sensing environment must use a combination of sensing modalities to best capture the environment. Signal processing provides the analysis, synthesis and modification of signals and is primarily responsible for separating the sensor signal from the environmental noise. Networking allows both for coordination between vehicles, but it also provides a conduit for fusing disparate information to provide an improved model of the environment. Artificial Intelligence is the primary engine that takes this information and turns it into an action within the required response time.

This "signal processing chain" is used to provide different levels of decisions leading to autonomy. Currently, there are five levels of autonomy recognized.

- Level 0: (now) – no automation and the driver is in complete control
- Level 1: (now) – function-specific automation where the driver can easily regain control from the specific function
- Level 2: (2013+) – combined function automation where driver is temporarily relieved of those driving functions; barely here now

Level 3: (2020+) – limited self-driving automation where the driver must be available to take over controls

Level 4: (2025+) – full self-driving automation where the driver is not expected to take control at any time

ROLE OF VERIFICATION

There are many flavors of product testing, e.g., certification, validation and verification, but all are designed to ensure the product meets specifications, fulfills its intended purpose and is safe to use. Most often, this process is performed by a third party that is unbiased and technically strong and involves repeated testing of a product to determine its selectivity, accuracy, repeatability, reproducibility and suitability. For CAV, testing should be done on pre-defined test scenarios that will stress all elements of the system. Pre-defined scenarios consist of predictable test cases, which the system will be subjected to on a regular basis, and unpredictable test cases. An example of a predictable test cases might include an autonomous vehicle picking up a passenger at an airport baggage claim. An unpredictable test case might include a white semi-tractor trailer pulling out in front of a car with a bright sun in the background. Unpredictable test cases are most often "six-sigma" events: They are rare, unpredictable and will have the most impact on ensuring CAV technology meets specification, fulfills its intended purpose and is safe for humans. To determine test cases, the federal government will need legislation that creates or delegates power to an organization that functions like the NTSB for aviation safety. This organization must gather data, analyze, document and report on all incidents across the country so that technology developers, manufacturers and independent testing can benefit from the lessons learned to create vehicles that are safe.

To do this, we suggest a holistic and systems oriented approach to testing based on four levels of testing. Each approach has advantages, and a robust test environment is useful only if it includes all approaches.

Digital simulation models the system and the environment for a given test scenario. Because it is a model-based simulation, it is inexpensive to repeat and the scenario can be easily controlled. The primary disadvantage with digital simulation is that it is a model of both the system and the environment, and if the model is not correct, the results will also be incorrect.

Hardware-in-the-loop emulation simulates only the environment by creating a scenario and modeling the input to the system's sensors, i.e., scenes are created much like a video game and played into the real CAV system. Because this approach only creates a model of the environment, it typically leads to a more robust test than simulation. Like simulation, testing can be easily controlled, is inexpensive to repeat and can easily be extended (e.g., what if the white tractor trailer was blue, or what if it pulled out 5 secs earlier, …). Because this approach depends on a model of the environment, it may not always have the fidelity needed to absolutely verify functionality. For this reason, a closed-test complex is needed to do real testing and verify the results on both digital simulations and hardware-in-the-loop emulations.

A closed-test complex is a test track that ultimately provides a large and flexible theater where the autonomous vehicle and its actors are real. Test tracks lack both controllability and repeatability and are expensive, but they test real scenarios and are an important part of confirming functionality and developing models that support simulation and emulation.

Public open road testing is the testing of systems on real highways and in cities. This approach often results in multiple scenarios all happening in real-time. It is expensive to repeat, and it is impossible to control, but it most accurately reflects the real environment. Many companies are now using public open road testing as their only approach to developing fleets of CAV and this can be very dangerous. Open road testing is more applicable for demos than for testing since they are not controllable and will not exercise those rare events that happen only once in a million times.

TEST CENTERS

The federal government can have a very constructive role in enabling this transformative technology through research funding, through safety consortiums that investigate and provide factual data around AV accidents and through creating quasi-governmental organizations much like the Department of Energy (DOE) and the Department of Defense's (DoD's) Federally Funded Research and Development Centers (FFRDCs) and University Affiliated Research Centers (UARCs) that conduct applied research and provide unbiased technology expertise to the government.

The Florida Turnpike Enterprise (FTE), Florida Polytechnic University (Florida Poly) and the Orlando Smart City are in a unique position to build a holistic test environment that could be used to provide certification of standards and national policies for CAV. As part of this holistic environment, Florida Poly is building the Advanced Mobility Institute which will provide digital simulation, Hardware-in-the-Loop emulation and layered services for the closed and open test grounds. FTE is building SunTrax, which provides an advanced state of the art closed facility test center for CAV. This test track represents an approximate $150M investment in a 400+ acre facility that provides complex test scenarios to users and can be easily reconfigured to adapt to evolving test cases. Both Florida Poly and FTE are members of the larger Orlando Smart Cities project that provides a testing platform on the public streets in the City of Orlando. The region also includes the University of South Florida's Center for Urban Transportation Research (CUTR), which focuses on transportation policy, regulations and standards.

Florida Poly is a new public STEM University with a focus on emerging technologies in computer science, electrical and computer engineering, mechanical engineering and data analytics. It has an applied research function modeled after DARPA, and it is focused on bridging the technology "Valley of Death" by translating fundamental research out of the University and into the market place. Florida Poly is developing deep expertise in technology development, testing and evaluation by modeling approaches used in mature industries like chip design and Defense to create a "science of CAV testing". The University is also developing educational programs in CAV with plans to offer distance education to professionals and executives in CAV with certifications. It is strategically located in Lakeland at the heart of Florida's High-Tech Corridor, which includes 23 counties and three fellow State University System public institutions. Lakeland is easily accessible from two of Florida's largest metropolitan areas, Tampa Bay and Orlando. They have combined populations of nine million people and nearly 70 percent of the state’s high-tech companies, creating opportunities for industry, government and academic collaborations.